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Status of developing a superconducting undulator prototype at SSRF

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Ⅰ. INTRODUCTION

A superconducting undulator has many advantages, such as a short period length, a high magnetic field strength, and a flexible adjustability of both magnetic field strengths and polarization modes. When applied in a synchrotron radiation light source, a superconducting undulator can produce x-rays with a high strength and a high brightness, which could be used in many applications, such as biological molecule structure determinations, early stage cancer diagnosis and treatments. A superconducting magnet for a superconducting undulator is required not only to withstand the long time high energy x-ray radiation, and the heat arising from x-rays beam imaging currents, but also to meet the demanding requirement of producing an ultra short period magnetic field with same amplitudes and phases[1,2,3,4]. In this paper, the status of developing a 1.1 T superconducting undulator prototype SU15 with a period length of 15 mm and a period number of 20 at SSRF is reported. The progress and technical details of magnet design, cryostat design and magnet winding are presented.

Table 1: X-ray energy ranges needed for different applications

Method	Energy (keV)	Application
KES	20-60	Imaging of lungs and hearts
CT	20-90	Imaging of bronchi, skeletons and brains
MRT	80-120	Treatment for nervous systems and tumors

Table 2: Parameters of a permanent magnet undulator and SU15

Item	PMU	SU15
Peak field B_{max} (T)	0.94	1.1
Period length (mm)	25	15
Magnetic Gap (mm)	6	6.5
Number of periods	80	20

Ⅱ. MAGNET DESIGN

The 20 pairs of coils are pre-stressed by a special bandaging system which consists of two pair of stainless steel plates, stretched together by bronze screwed rods. The pre-stressing can restrict the movement of the superconducting wires in magnetic fields and protect the undulator from quenches. The sketch of undulator magnet structure is given in Fig. 1. The magnetic gap is 6.5 mm. There is a copper liner which can shield heating from the electron beam. The spectral brightness of SU 15 and current insertion devices are calculated as shown in Fig. 2.

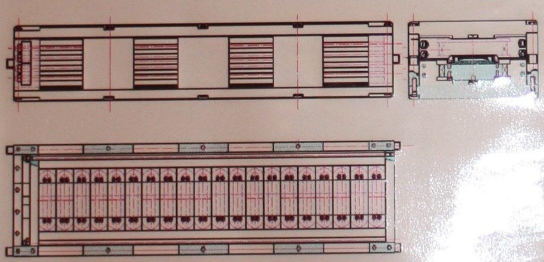

Fig. 1 Sketch of SU15 magnet structure

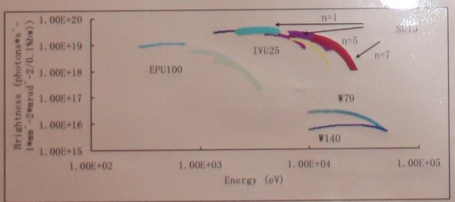

Fig. 2 Spectral brightness of SU15
E=3.5 GeV, I=210 mA, ε=3.9 nm·rad

Ⅲ. CRYOSTAT DESIGN

SU15 cryogenic system consists of an external vacuum chamber, a 50 K heat-radiation-reducing shield, 4 1.5K@4.2K G-M cryocoolers with the first level cooling heads connected to the current leads and the 50 K thermal shield, while the second level cooling heads connected to the magnet array, and a liquid helium vessel with a filling tube.

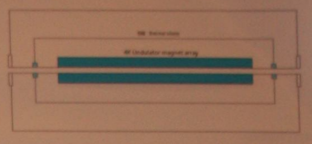

Fig. 3 Sketch of SU15 cryostat

Ⅳ. MAGNET WINDING

1. The magnet structure design, magnetic field calculation and cryostat design of SU15 have been completed already, as shown in Fig. 1, Fig. 2, and Fig. 3.
2. NbTi wire performance test and test coils design have been done as shown in Table 3 and Table 4.
3. To valuate the performance of NbTi wires and verify the winding techniques, solenoid and racetrack test coils have been winded using a specially designed winding machine, as shown in Fig. 4 Fig. 5, …, Fig. 11.

Table 3 Specifications of the NbTi wire

Cu/SC ratio	1.3
R.R.R.	174.3
Filament diameter (μm)	95
Number of filaments	54
Wire width (mm)	1.28
Wire thickness (mm)	0.83
Critical current at 4.2K	510A@7T

Table 4 Parameters of test solenoid coils

Number of layers	22
Number of turns per layer	32
Total number of turns	704
Current per turn （A）	332
Average current density (A/mm²)	312
Peak field of the coil (T)	4.82

Fig. 4 A test NbTi solenoid coil

Fig.5 A test NbTi racetrack coil

Fig.6 Coil winding machine

Fig.7 Epoxy impregnation of coils

Fig.8 NbTi solenoid test coils at baking

Fig. 9 A test coil on a cryogenic support

Fig.10 Measurement system

Fig. 11 A test dewar and a 500A DC power supply

Ⅴ. CONCLUSIONS

1. The magnet structure design, magnetic field calculation and cryostat design for a superconducting NbTi undulator prototype SU15 at SSRF have been carried out.
2. Test solenoid and racetrack NbTi coils have been winded and impregnated with a special kind of epoxy.
3. SU15, a 1.1 T superconducting undulator prototype with a period length of 15 mm and a period number of 20, is scheduled to be assembled and tested in 2015 at SSRF.

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